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LIDAR FOR ATMOSPHERE RESEARCH OVER AFRICA – A TRILATERAL RESEARCH PROGRAMME (LARA - TRIP)

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ABSTRACT

This paper describes the importance of LIDAR for atmosphere research over Africa and the initiatives being undertaken to foster such research. A mobile LIDAR system is to be employed for field campaign measurements over different locations around South Africa and Africa.

1. INTRODUCTION

In recent years, the importance of systematic monitoring of the atmospheric structure and dynamics has been highlighted by several atmospheric research campaigns over the globe. Laser radar, more popularly known as LIDAR (LIght Detection And Ranging), has become an excellent tool for monitoring the atmosphere in a relatively short period of time (a few seconds to minutes). Furthermore, interpretation of the results can accurately reflect the state of atmosphere at the time of the measurements. The discovery of different laser sources and improvements in detector technology, data collection and analysis techniques, have made the LIDAR a consistent remote sensing tool for atmospheric science. Both continuous wave and pulsed laser systems have been extensively used. These systems are currently operational and are used for the study of the atmospheric structure and dynamics, trace constituents, aerosols, clouds as well as the boundary layer and other meteorological applications. LIDARs are used notably in different parts of the globe to study aerosols/clouds (Mie Scattering), atmospheric density and temperature (Rayleigh Scattering), metallic ion species (Resonance Scattering), minor constituents and

trace gases (Differential absorption), composition (Raman Scattering) and winds (Doppler LIDAR). For further details, one can refer to the recent chapter on 'LIDAR for ground and air borne trace gas detection' in a text book 'Lasers in chemistry' [1].

The first establishment and construction of a LIDAR system was made in 1961, by two groups at Hughes Aircraft Malibu and Culver City, respectively. However, this system was exploited for a range finding application only. Later, LIDAR studies were carried out using a Ruby-laser as source [2][3][4] but recent studies have taken advantage of high pulse repetition frequencies available with Neodymium (Nd)-Yttrium Aluminum Garnet (YAG) lasers, the frequency-doubled output at 532 nm being employed for atmospheric studies [5]. Advantages offered by the improved performance of Nd:YAG lasers, the use of shorter wavelengths, and the availability of improved blocking for rejecting the elastically backscattered return, have led to renewed interest in atmospheric density measurements. The Nd:YAG laser is also advantageous since it can be easily tuned to make atmospheric measurements on aerosols, clouds, water vapour, ozone and metallic ions.

1.1 LIDAR survey

A survey of ground based LIDARs around the world was conducted via a web search. It is noted here that the survey is not by any means comprehensive and conclusive. Further, the survey has been made with regards to LIDAR applications for atmosphere studies

including pollutant monitoring. The following salient features are noted from the survey that:

- around 80 % of the LIDARs are in the northern hemisphere region,
- only a few, approximately 20 %, exist in the southern hemisphere region with a high concentration in South America,
- LIDARs in the African continent are limited to two system which includes the mobile LIDAR recently developed at Pretoria,
- even though there are many ground based standard LIDARs, there are not many mobile LIDAR systems for systematic atmosphere measurements over different locations.

Only two LIDAR systems are available in South Africa. One is located in Durban (South Africa) and operated under a South Africa – France association by University of Kwa-Zulu Natal (UKZN) [6], [7] and the other one is the new mobile LIDAR system designed and developed at the National Laser Centre (NLC), Council for Scientific and Industrial Research (CSIR), Pretoria. Our aim is therefore to develop a mobile LIDAR system to serve as a research platform for monitoring the atmosphere over Africa.

2. OBJECTIVES AND DESCRIPTION

The research objective is to obtain a sustainable LIDAR for probing the atmosphere. At present, the research programme is focussed to obtain a better understanding of global climate change (GCC) and global warming (GW). The two important factors influencing GCC and GW are water vapour and ozone. Regular monitoring of these constituents is important for a better understanding of GCC and GW. To achieve this, we need a mobile instrument which would facilitate measurements at different regions. To accomplish the above requirements, the LIDAR will be installed in a mobile vehicle equipped with the necessary optics to make remote measurements. Our goal is to build the mobile LIDAR system and to measure the following in three years period of time;

- Mie scattering of particulate size (μm) matter in the atmosphere (Year – 1)
- Aerosol measurements and Cloud

characteristics (Year – 1)

- Water vapour measurements in the lower troposphere region up to 8 km (Year – 2)
- Ozone measurements in the troposphere regions up to 18 km (Year – 3)

The study on particulate matter will address knowledge on particle size and concentrations in the atmosphere. Making observations over different regions/places provide an idea of mass transport between the regions and through trajectory analysis to identifies the location of the source, e-g., Bio-mass burning. Aerosols/clouds play their roles in the earth-radiation budget and LIDAR has the unique capability of measuring the particle concentration at a particular place in an effective manner by illuminating different harmonics of the laser (Nd:YAG). At present, the radiative effects of aerosols create the largest uncertainty in global climate predictions to quantify climate forcing caused by man-made changes to the composition of the atmosphere. LIDAR retrieved measurements will provide reasonably accurate information. It also has the potential to locate the height and distribution of various clouds which are present. The relative thermodynamic phase distribution of the cloud, water/super-cooled water, ice and ice crystal, can be examined to some extent, based on the depolarization characteristics of the LIDAR back scattering and linear depolarization ratio. Once, we are capable of applying the LIDAR for aerosol/cloud measurements, the LIDAR system will be upgraded for measuring water-vapour in the lower troposphere. This would be performed with initial site measurements and then campaigns over other locations around South Africa/Africa. The water-vapour measurements over different regions will address the level of water vapour present in the atmosphere. It addresses the dry and wet regions, and thereby focuses on the ecological effects (such as, agriculture and water scarcity). Since water-vapour is a primary green-house gas, the study further addresses issues such as GCC and GW. The aim is to upgrade the LIDAR system to be capable of making troposphere ozone measurements. It elucidates the amount of ozone in the troposphere height regions and one would be able to infer ozone depletion and increases in temperature (in other words, global warming due to increase in ground ozone).

Besides regular monitoring, measurements at different places would provide a better knowledge of concentrations and its localized variation with respect to place. The mobile LIDAR system will enable us to fulfil our objective of making measurement in different places, especially in South Africa and African countries (Ethiopia and Malawi).

This research programme is also aimed to improve research related relationships between the countries and our understanding of aerosol and cloud characteristics in the sub-tropical southern hemisphere. A kind of triangular LIDAR research network is established between the LIDAR located in NLC-CSIR Mobile LIDAR at Pretoria, Laboratoire de l'Atmosphère et des Cyclones de La Réunion, CNRS 8105 at Reunion and University of Kwazulu Natal (UKZN), Durban.

3. LIDAR SPECIFICATION

Based on the literature survey, we have proposed a typical specification of the planned mobile LIDAR. The details are given in the following table.

Table 1. Specifications of the planned mobile LIDAR

Transmitter	
Laser Source	: Nd: YAG, Continuum
Operating Wavelength	: 1064, 532, 355, 266 nm
Average energy per pulse	: ~200 mJ (at 532)
Beam Expander	: 3 x
Pulse width	: 7 nsec (Typical)
Pulse repetition rate	: 10 Hz
Beam Divergence	: 0.6 mRad
Receiver	
Telescope type	: Newtonian
Diameter	: 404 mm
Field of View	: less than 1 mRad
Filter band width	: 0.7 nm
Raman cell	
Length	: 150 cm
Diameter (inner/outer)	: 20/55 mm
D ₂ pressure / purity	: 10 bars / 99.7 %
He pressure / purity	: 24 bars / 99.999 %
Signal and Data Processing	

PC based photon counting system operating under Ethernet controlled LICEL real-time software.	
Bin width (Range Resolution)	: 0.2 - 2 μ sec (30 - 300 m)
Integration time	: 50-1000 sec

4. PRESENT SCENARIO

The mobile LIDAR system has been initially designed and aimed for first field campaign measurements in a few months and the system is to be employed for the backscatter measurements (Aerosols/clouds) and for the height region from ground to 35 km. Figures 1 and 2 represent the external view of the mobile LIDAR van and the LIDAR system set-up respectively. A more detailed system description is explained in the companion paper [8].



Figure 1. The external view of mobile LIDAR van.

The LIDAR measurements will be calibrated with other in-situ (for e-g., Sun Photometer, Radio-meter, Balloon borne), space-borne (Stratospheric Aerosol and Gas Experiment - SAGE, Cloud-Aerosol LIDAR and Infrared Pathfinder Satellite Observation - CALIPSO, Moderate Resolution Imaging Spectro-radiometer - MODIS) and different network data sets (Aerosol RObotic NETwork - AERONET, Network for the Detection of Atmospheric Composition Change -

NDACC), Global Atmosphere Watch – Aerosol Lidar Observation Network (GALION).

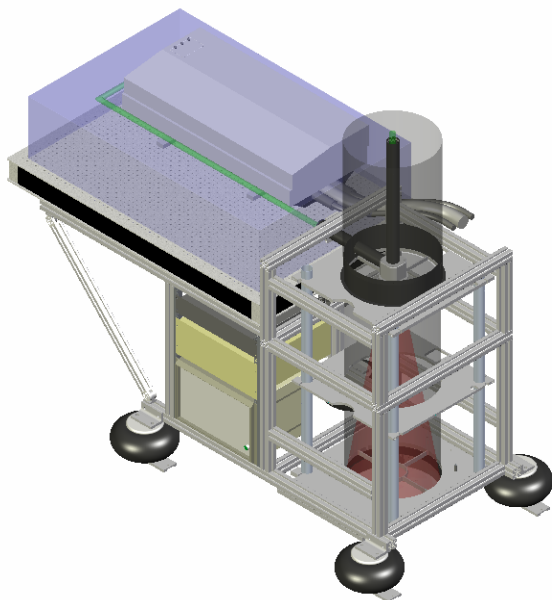


Figure 2. The present LIDAR set-up inside the van.

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